# THE EFFECTS OF MESQUITE BEAN CONSUMPTION ON RUMINAL pH OF CATTLE AND GOATS

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THE EFFECTS OF MESQUITE BEAN

CONSUMPTION ON RUMINAL pH of CATTLE AND GOATS

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## ACKNOWLEDGEMENTS

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## ABSTRACT

Mesquite (*Prosopis glandulosa* Torr.) beans are a food source high in sugars and carbohydrates found in abundance for short periods of time in Texas. Although nutritious, mesquite beans may induce acidosis or a conditioned food aversion in livestock. Five cows were fed 0, 20 and 40% of their diet in mesquite beans over a period of 28 days. The outcome was rumen pH levels decreased from 0 to 20% and then further decreased at 40%. Rumen pH reached levels near 5, but cows apparently did not experience acidosis. The goat study consisted of 22 yearling nanny goats. Half of the goat's water was dosed with 2% sodium bicarbonate and they were fed 300, 500 and 700g of mesquite beans each per day in addition to alfalfa pellets; refusals were weighed. Goats that received sodium bicarbonate consumed less mesquite beans indicating that goats did not experience acidosis.

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## INTRODUCTION

Mesquite (*Prosopis glandulosa* Torr.) bean pods are readily consumed by livestock and wildlife during the summer months in West Texas (Ansley et al., 2017). As a food source for ruminants, mesquite bean pods contain both simple sugars and complex carbohydrates that are easily digested in the rumen resulting in the rapid release of volatile fatty acids (VFAs) (Becker and Grosjean, 1980). The rapid release of the VFAs propionate and lactate can lead to rumen acidosis especially when ruminants consume a diet consisting primarily of roughages (Giger-Reverdin, 2017). The rapid release of propionate and lactate lowers rumen pH and alters rumen microbial populations (Sanders et al., 1980). Others have illustrated that acidosis results in aversive postingestive feedback and the formation of conditioned food aversions (Phy and Provenza, 1998). When aversive feedback occurs, ruminants typically select alternative forages. Thus, over-consumption of mesquite beans may occur when alternative nutritious forage is limited.

Once aversive postingestive feedback is experienced, animals avoid those foods and flavors that were associated with feedback in the past (Provenza, 1995). This neurological mechanism allows animals, including grazing animals, to recognize harmful foods and avoid foods that cause malaise and interfere with metabolism. When nutritious alternative foods are limited, animals may be forced to consume foods that have resulted in aversive feedback in the past. Plant-induced toxicosis is often the result of grazing animals unable to meet nutritional requirements unless poisonous (aversive) plants are included in the diet (Provenza, 1995).

While acidosis is typically not considered plant-induced toxicosis, lower rumen pH interferes with normal metabolism and results in livestock death in the most extreme cases. Given the high sugar content of mesquite beans, reports of mesquite bean toxicosis may be the result of over-consumption of mesquite beans and subsequent acidosis when nutritious alternative forages are limited.

## OBJECTIVE

For this study, different levels of mesquite beans were fed to determine (1) the level of mesquite bean consumption that is sufficient to induce acidosis in cattle and goats, and (2) if over-ingestion of mesquite beans results in aversive postingestive feedback and the formation of a conditioned food aversion.

## LITERATURE REVIEW

Mesquite is the most common invasive woody plant in the southern and western regions of Texas. Where mesquite is found in high densities, herbaceous forage production is depleted (Kneuper et al., 2006), thereby reducing the amount of available energy for grazing ruminants like cattle. Cattle may resort to the consumption of different energy sources, including mesquite pods when nutritious herbaceous forage is limited. In the summer months, when the mesquite pods would be available to livestock, herbaceous forage production is often limited by hot and dry conditions.

Mesquite is a highly adapted tree that evolved to produce more bean pods in dry years. Conversely, pod production is often limited and plant production is enhanced in years with above average annual precipitation. Thus, below average rainfall during the summer may both limit herbaceous forage production and enhance mesquite pod formation. In turn, the utilization of mesquite pods for alternative energy source is increased during summers characterized by below average precipitation.

The fruit that is grown from a mesquite tree grows as a long strand of beans encapsulated in a pod. Inside the outer green and waxy layer of the pod is a layer of sugars that is mostly sucrose with the innermost layer of the fruit being the seed itself. The dietary breakdown of the mesquite bean has a protein level of 13% and the total level of sugar totaling to 30% (Becker and Grosjean, 1980). When livestock consume high levels of sugars and carbohydrates, like those found in mesquite bean pods, there will be a potentially larger reduction in rumen pH found when compared to a strictly roughage diet (Giger-Reverdin,

2017). The consumption of these mesquite pods when the animal is not conditioned to the high levels of dietary components such as sucrose, could cause a state of ruminal acidosis.

Additionally, the consumption of mesquite pods could have an additional dietary consequence. As stated by Sanders et al., (1980), mesquite beans have been found in the tract of beef cattle for as long as nine months after the last possible day of consumption. This extended period of digestion required for the pods could potentially cause some blockages within the gastrointestinal tract of the livestock. The rapid digestion of glucose and the lessoned digestion of the cellulose will lead to rumen compaction and a decrease in average daily gain, leading to a decrease in overall productivity (Cook et al., 2008).

Toxicosis within livestock can come with many different outward shown symptoms as well as some more difficult to observe. Some of these symptoms include twitching of the lips, head tremors, excessive salivation, emaciation and some more serious symptoms such as muscle atrophy, anemia, decreased blood glucose levels and amino acid imbalances (Cook et al., 2008). As stated by Tabosa et al., (2006), goats with long term consumption of mesquite bean pods started to develop mandibular tremors, mainly during the act of mastication. In addition to the mandibular tremors and difficulty swallowing, other neurological effects occurred as the result of amino acid imbalances, causing a neuropeptide deficiency and further causing paralysis of the trigeminal nerve.

## MATERIALS AND METHODS

Cattle Study: This study consisted of five ruminally cannulated nonparous cows at the Angelo State University Management, Instruction and Research (MIR) Center. Cows were placed into a Latin square study design, where each of the cows started off with zero percent mesquite bean pods for seven days, a seven day adjustment period (basal diet and no mesquite pods). Thereafter, cows were fed a diet consisting of 20% mesquite bean pods for seven days, followed by a seven day adjustment period. For the last seven days, cows were subjected to a diet of 40% mesquite bean pods. Intake was monitored daily. Rumen pH was measured on day 0, 3 and 7 during each seven-day feeding period. Rumen pH was measured at hours 0 and 12 after diet change to determine changes in rumen pH as the amount of mesquite pods in the diet increased.

Goat study: this study consisted of 22 weaned Boer-cross female goats housed at the Angelo State University MIR Center. Goats were approximately 6 months old and weighed 26 kg. Following a five day period to adjust to their pens and alfalfa pellets, goats were fed three different levels of mesquite beans (300, 500, and 700 g). The remainder of the diet consisted of alfalfa pellets, fed at 2.5% BW to meet maintenance requirements. All goats received 300 g of mesquite beans on day 6 through 10. On days 11 through 15, 500 g of mesquite beans were fed, followed by feeding 700 g of mesquite beans on day 16 through 20.

Goats were randomly assigned to each treatment and were fed treatment diets for 5 days. Of the 22 individual goats used, 11 of the individuals had their water treated with sodium bicarbonate at a 2% aqueous solution (*ad libitum*), while the other 10 individuals were given untreated water (*ad libitum*). In other studies, the same protocol was used to

alleviate acidosis for over ingestion of grain (Phy and Provenza, 1998). Each individual goat's diet was be weighed daily before feeding and the refusals were weighed following the feeding period to monitor intake. The offered amount of mesquite beans were available to the goats for one hour before the refusals were removed and weighed. Following the mesquite beans, the goats were fed alfalfa pellets at 2.5% BW to meet maintenance requirements.

Throughout each feeding trial, cattle and goats were housed in individual pens and the cattle were fed a basal ration (Table 1), goats were fed alfalfa pellets (2.5% BW) to meet maintenance requirements (National Research Council, 2007; National Academy of Sciences, Engineering, and Medicine, 2016). Each individual was offered fresh water (*ad libitum*). Cattle were fed a basal ration at 9 kg per individual $\cdot$ day$^{-1}$ while goats were fed alfalfa pellets at 2.5% BW to meet maintenance requirements. In addition, the cattle also received sorghum hay (*ad libitum*). Cattle were housed in 6.1 m × 24.4 m individual pens while goats were housed in 1 m × 1.5 m individual pens. All research protocols were approved by Angelo State University Institutional Animal Care and Use Committee (IACUC).

Rumen pH data for the cattle study was analyzed as a Latin square design using an analysis of variance with the amount of mesquite beans fed as the main effect and day of feeding as the repeated measure. Data for the goat study was analyzed as a repeated measures analysis of variance with level of mesquite pods in the diet as the main effect, individual animals nested within treatments serving as replications and day of collection as the repeated measure. Means were separated using Tukey's Protected LSD with $P \leq 0.05$ and data was analyzed with the statistical package JMP (SAS Institute, 2007).

Table 1. Ingredients and nutrient content of basal ration.

| Ingredients/Nutrients | As fed (%) |
|---|---|
| Alfalfa Pellets | 10.0 |
| Cotton Seed Meal | 12.5 |
| Cottonseed Hulls | 31.5 |
| Cane Molassses | 3.5 |
| Premix | 2.5 |
| Corn | 40.0 |
| DE | 2.6 Mcal/kg |
| TDN | 59.0 |
| Crude Protein | 14.5 |
| Crude Fiber | 14.2 |

## RESULTS

Cattle Study: Prior to feeding mesquite beans, cows had a mean ruminal pH of 6.02 ± 0.06. Rumen pH declined as the percentage of mesquite beans fed increased from 0 to 20% of the cattle's ration, and again as the amount of mesquite beans increased to 40% of the diet. At 20% of the diet, ruminal pH decreased to 5.7 ± 0.05. Once the percentage of mesquite beans in the diet was increased to 40% of the diet, rumen pH declined to 5.37 ± 0.05. The hypothesis that mesquite beans would lower rumen pH was accepted.

There was a constant decline in rumen pH across the different treatments (Fig. 1). Rumen pH declined across days when mesquite beans were fed at 20% of the diet (Fig. 2) and again at 40% of the diet (Fig 3). However, cattle did not apparently experience any acidosis pH levels (< 5.00) on any of the samples taken throughout the study. Cattle continue to consume all of the mesquite beans offered and all of their basal diet. The hypothesis that over-consumption of mesquite bean would result in aversive postingestive feedback and avoidance of mesquite beans was not accepted based on the data from this study.

Goat Study: Mesquite bean intake varied by treatment (Fig. 4) and by day (data not shown). The treatment by day interaction was also significant (Fig. 5). Goats in the control group ate more mesquite beans than goats receiving sodium bicarbonate in their water. Across the 15 days of feeding mesquite beans, goats in the control group consistently ate more mesquite beans than goats receiving sodium bicarbonate except for days 6, 10, and 15 (Fig. 5). Goats did not appear to be suffering from acidosis or reduce intake because of aversive postingestive feedback. Goats gained weight from the beginning to the end of the study (day effect $P < 0.05$) (Table 2), but the treatment and treatment by day effects were similar.

Goats consumed all of the alfalfa offered each day (data not shown) regardless of treatment or day of feeding. The hypothesis that mesquite beans caused aversive postingestive feedback and an overall reduction in intake was rejected.

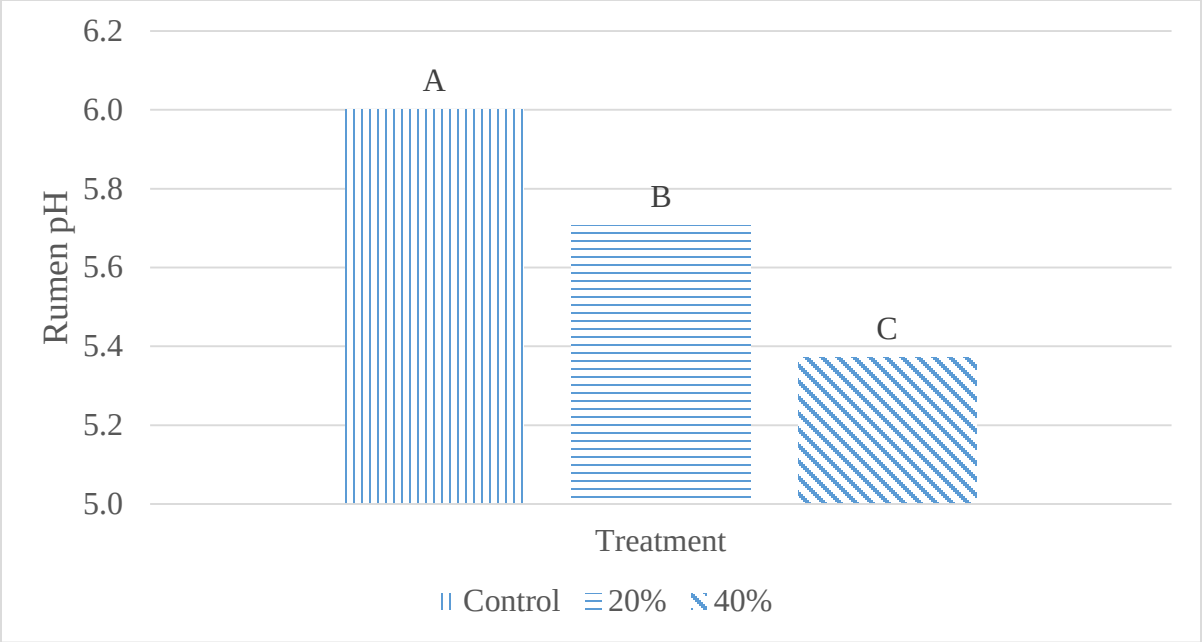


**Figure 1.** Mean pH taken 12 hours after feeding mesquite beans. Cattle received a diet consisting of either 0 (control), 20%, or 40% mesquite beans. Bars with different superscripts, differ ($P<0.05$).

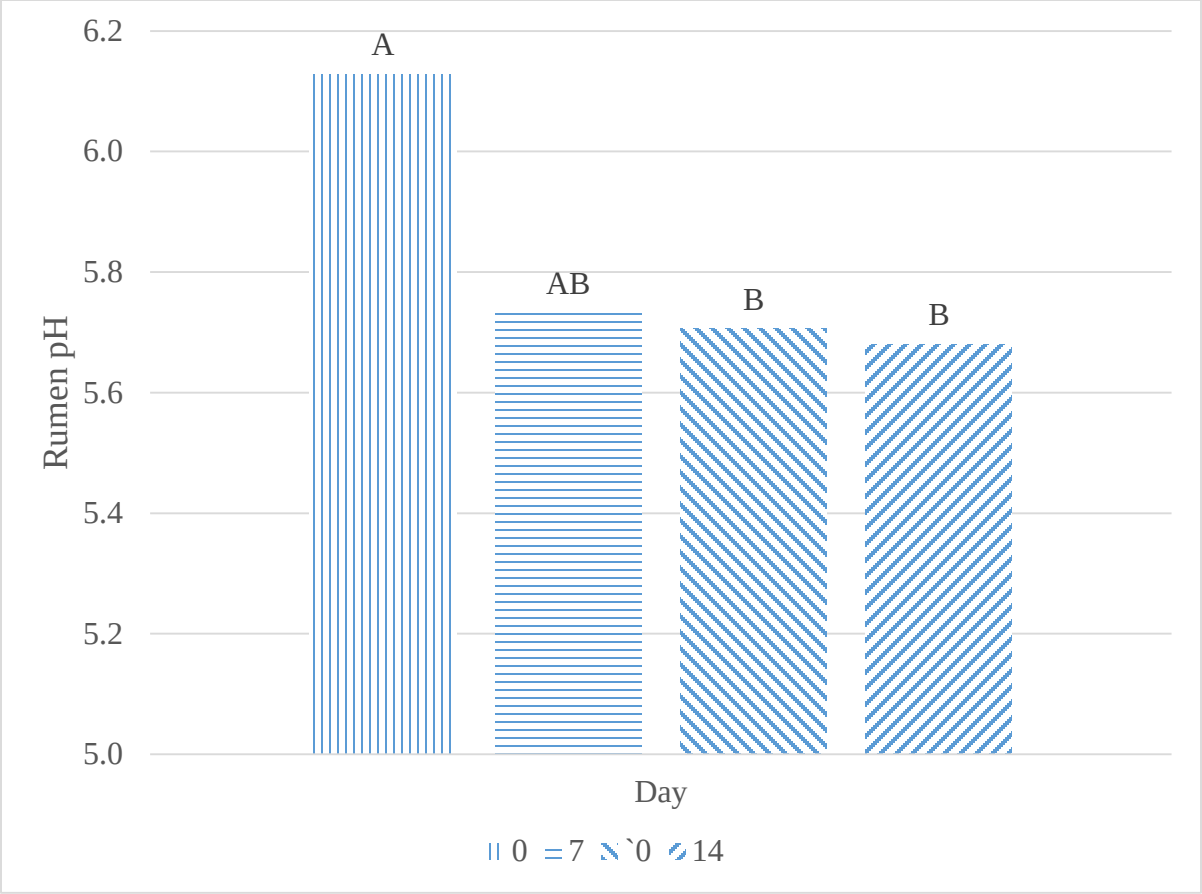


**Figure 2.** Change in rumen pH when cattle were fed a diet consisting of 20% mesquite beans on days 0-14. Bars with different superscripts, differ (P<0.05).

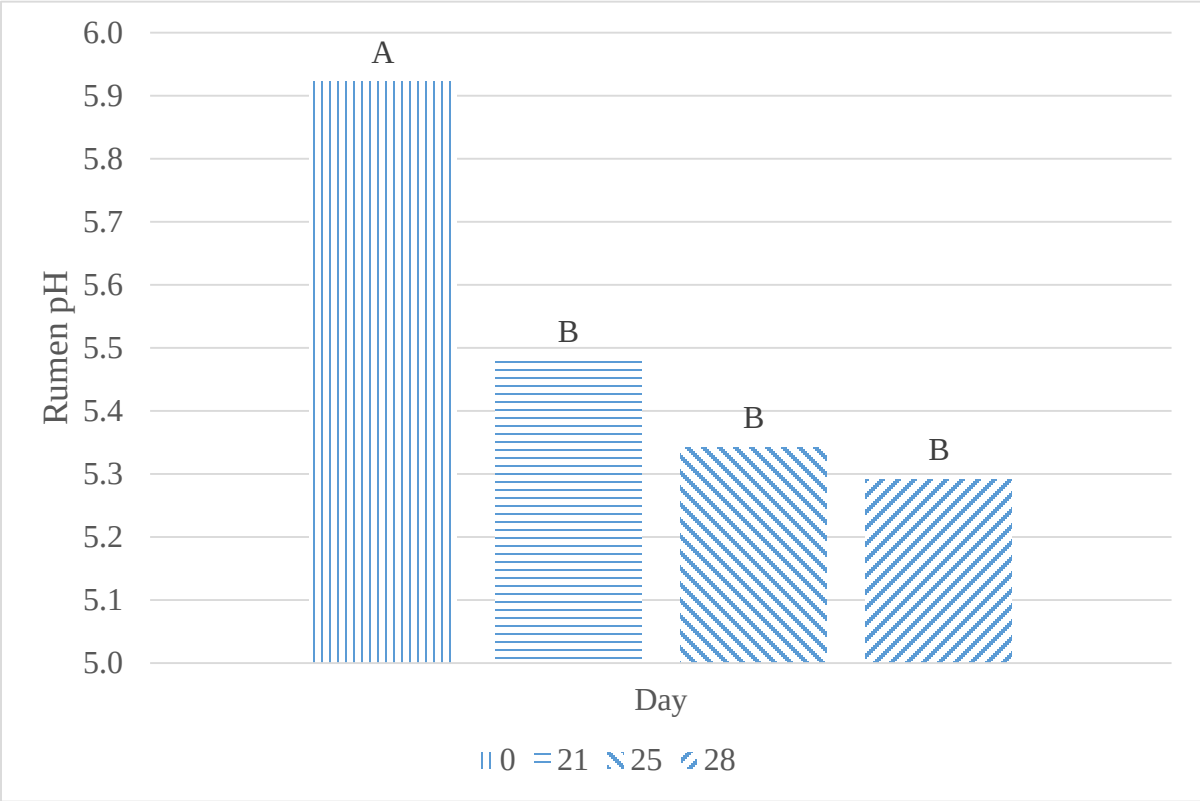


**Figure 3.** Change in rumen pH when cattle were fed a diet consisting of 40% mesquite beans on days 0-28. Bars with different superscripts, differ ($P<0.05$).

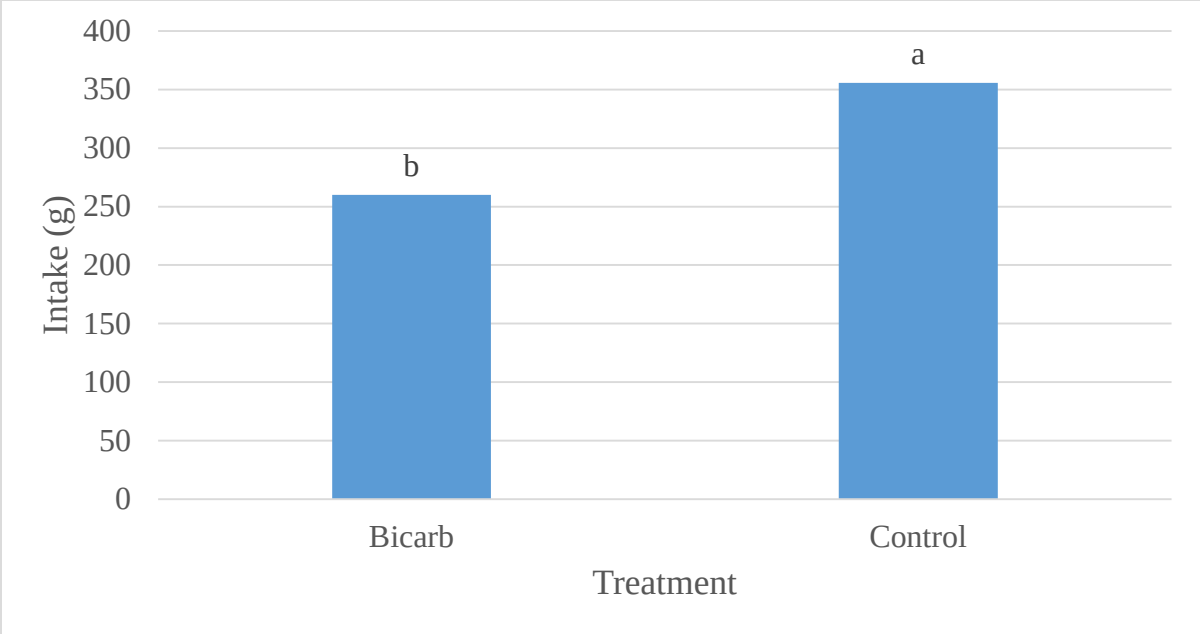


**Figure 4**. Average consumption of mesquite beans in g, from days 6-20. Treatment received water with 2% Sodium bicarbonate while control received water without Sodium bicarbonate.

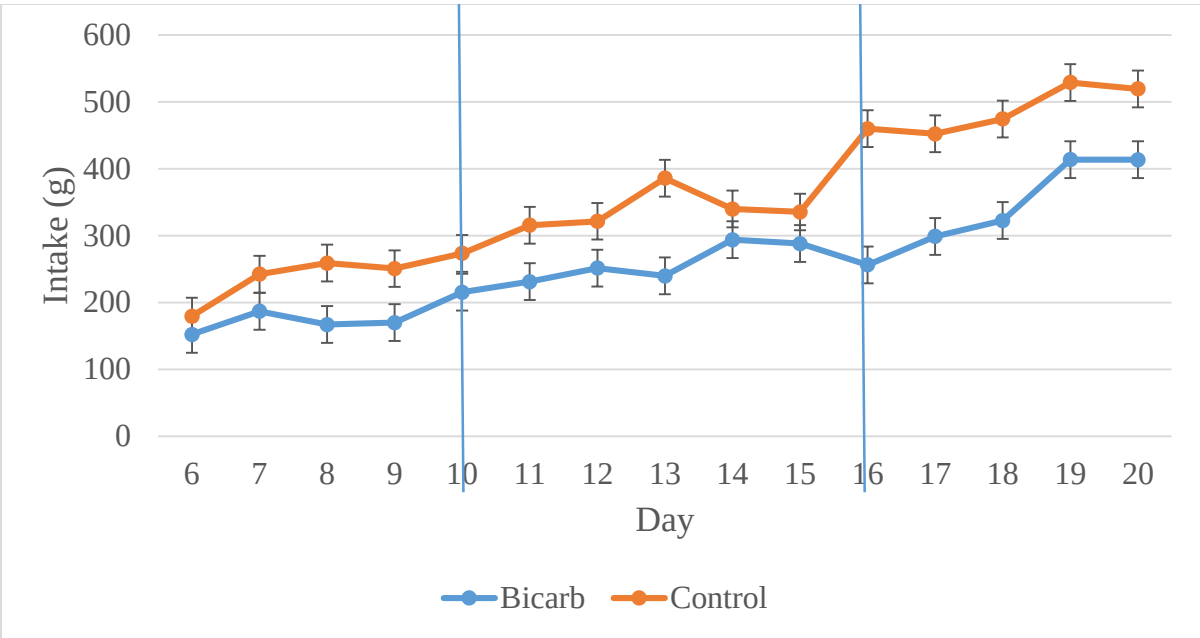


**Figure 5**. Average consumption of mesquite beans in g, from days 6-20. Treatment included water with Sodium bicarbonate 2% while control received water without Sodium bicarbonate. Vertical lines signify a change in mesquite beans offered (300, 500 and 700 g, respectively).

Table 2. Average weight (kg) of goats at day 1 and day 20 of the study. Day effect was significant but the treatment and treatment by day interactions were similar.

| Treatment | Initial (Day 1) | Final (Day 20) | SEM |
|---|---|---|---|
| Sodium bicarbonate | 25.1 | 26.2 | 1.1 |
| Control | 27.4 | 28.6 | 1.1 |
| Day Effect | $26.2^{b}$ | $27.4^{a}$ | 0.8 |

## DISCUSSION

Cattle Study: As the amount of mesquite beans in the diet increased from 0 to 20% and again to 40%, rumen pH declined, accordingly. Acute acidosis occurs when the rumen pH declines to 5 or less for extended periods without recovering to higher levels between feedings (Giger- Reverdin, 2017). By the end of the study, rumen pH had declined to levels near 5, sufficient to cause mild or subacute acidosis and the formation of a conditioned food aversion. However, cattle continued to consume all of the mesquite beans offered each day, regardless of the amount fed and subsequent drop in rumen pH. Apparently, the sugar content of the mesquite beans was sufficient to reduce rumen pH, but not induce acidosis. Goats can consume mesquite beans for short periods of time (<2 months) without an apparent toxicosis effect. Conversely, when mesquite beans are consumed for an extended period of time (2-10 months) there toxicosis becomes prevalent (Cook et al., 2008). Therefore, with the shorter feeding period of the cows, acidosis and toxicosis may have been avoided.

Cows were fed a complete diet that included sudangrass hay and a concentrate maintenance ration to meet nutritional requirements. The maintenance ration contained cottonseed hulls as a source of fiber. Any aversive postingestive consequences may have been alleviated by the amount of fiber in the cattle diets. Most cases of mesquite bean toxicity are reported during dry conditions when the amount of grass (roughage) in the diet is limited by a lack of forage quantity. The results of this study may have differed if less roughage was fed in the diet. On one day of the study, the cows were mistakenly fed hay before rumen pH samples could be collected. When they were collected, all rumen pH levels had risen to above 6. This suggests that the amount of fiber fed to the cows may have raised pH, allowing cows to avoid prolonged acidosis.

Well water on the ranch is relatively high in calcium carbonate, another compound known to alleviate acidosis and raise rumen pH. The amount of calcium carbonate in the water provided to cattle and goats may have raised rumen pH and alleviated the adverse effects of consumption of mesquite beans.

Intake of the basal ration and the percentage of the mesquite beans offered remained constant throughout the study, therefore there is no obvious evidence of toxicosis or rumen compaction of these cattle. If rumen compaction or toxicosis were present there should have been a drop in intake and altered behavior of the heifers within the treatment.

Goat Study: Preference for or an aversion to foods results from postingestive feedback (Provenza, 1995). Once aversive postingestive feedback is experienced, animals reduce intake or avoid the food. Conversely, positive feedback results in the formation of preferences for foods and flavors associated with nutrient release. The goats used in the study were on pasture with mesquite beans available before being used for the study and therefore were familiar with mesquite beans as a food source. This familiarity with this source of nutrition could have created a preference for or aversion to mesquite beans before the data collection occurred. Preference for foods that are high in energy declines after consuming multiple meals of that food source (Phy and Provenza, 1998). In other studies, goats would consume all of the mesquite beans offered each day (Kneuper et al., 2006; Cook et al., 2008). Most goats left some beans at each feeding interval after one hour of feeding. Previous experience with mesquite beans may have affected intake in this study. Likewise, the amount of fiber in the diet from the basal ration of alfalfa or the amount of calcium carbonate in the well water may have impacted intake as well.

Cook et al., (2008) explains that there is no toxicosis effect on goats that consume up to 60% of their diet in mesquite beans. By the end of the study, goats were consuming a diet of approximately 50% mesquite beans. This level may have been insufficient to induce toxicosis and a reduction in intake.

## IMPLICATIONS AND FUTURE RESEARCH

Based on the results of this study and others (Cook et al., 2008), mesquite beans can be consumed on rangelands without inducing acidosis as long as sufficient roughage is available through standing forage. Mesquite beans are nutritious and should improve the overall nutritional status of livestock on rangelands (Becker and Grosjean, 1980). Unfortunately, consumption of mesquite beans will result in seed dispersal across the landscape (Kneuper et al., 2006). Up to 80% of the mesquite beans consumed by cattle survived digestion and remained viable when deposited in feces. Conversely, passage through the digestive system of goats reduced the number of viable mesquite seeds (Kneuper et al., 2006).

Results of this study may have differed if the amount of fiber in the diet varied. Future studies should assess rumen pH as the amount of mesquite beans and fiber vary in the diet. Likewise, the amount of other compounds like calcium carbonate in water sources may impact rumen pH and the likelihood of aversive postingestive feedback. Future studies should vary the amount of calcium carbonate in water and the amount of mesquite beans fed.

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# APPENDIX

ANGELO STATE UNIVERSITY

College of Graduate Studies & Research

*Institutional Animal Care & Use Committee*

July 25, 2019

Cody Scott,
Professor
Agriculture
Angelo State
University ASU
Station #10888
San Angelo, TX
76909

Your proposed project titled, "The effects of mesquite pod consumption on ruminal pH of cattle and goats" was reviewed by Angelo State University's Institutional Animal Care and Use Committee (IACUC) in accordance with the regulations set forth in the Animal Welfare Act and P.L. 99-158.

This protocol was approved for three years, effective July 25, 2019 and it expires three years from this date; however, an annual review and progress report form (www.angelo.edu/content/files/22583-iacuc- annual-review-progressreport) for this project is due on August 15 of each year. If the study will continue beyond three years, you must submit a request for continuation before the current protocol expires.

The protocol number for your approved project is 2019-107. Please include this number in the subject line of in all future communications with the IACUC regarding the protocol.

Sincerely,

Chase
Runyan,
Ph.D.
Co-Chair, Institutional Animal Care and Use Committee

## VITA

I, Mark Daniel Zoeller grew up in Boerne, TX where I attended Boerne Samuel V. Champion High School and graduated in June of 2014. In the fall of 2014, I started my undergraduate career at Angelo State University, studying Natural Resource Management with a minor in Animal Science. After graduating in December of 2017, I began working towards a Master's degree in Animal Science from Angelo State University. While completing a master's degree, I did research using cattle and goats fed mesquite beans to observe some of the changes in rumen function. After graduation, I plan for working for Texas AgriLife Extension Service.